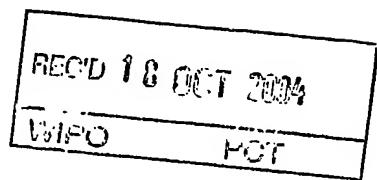


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Field of the invention

The present invention relates to a device for exchange of at least one substance, such as moisture, between at least two counter-current fluid flows, comprising a generally closed chamber having an inlet and an outlet for a first fluid flow, such that

- 5 the first fluid flow flows in a first direction from the inlet to the outlet inside the chamber; and at least one duct, which extends inside the chamber, generally in parallel with the first direction, which duct is arranged to conduct a second fluid flow in an opposite direction to the first direction and which duct comprise a duct wall material with high permeability to the substance to be exchanged and low
- 10 permeability to the fluids containing that substance.

The device is particularly useful for exchanging moisture from a first air flow to a second air flow, in order to desiccate the first air flow.

Prior art

Such devices are used e.g. for desiccating inlet air to a building, which inlet air is to

- 15 be fed to a refrigeration unit for cooling the inlet air. US 6,178,966 discloses a device, inter alia for exchanging moisture between an inlet air flow and an exhaust air flow in a building. This prior art device comprises, according to one embodiment, a generally rectangular chamber in which a number of ducts are arranged in parallel to the longitudinal axis of the chamber. The duct walls are made of a water vapor
- 20 permeable material. A first air flow is fed through the ducts and a second air flow is fed through the chamber outside of the ducts, so that the two air flows flow in a counter current fashion inside the chamber. During this counter current flow, moisture from one air flow penetrates through the water vapor permeable material into the other air flow, while keeping the air in the two flows separated from each other. This
- 25 allows for desiccating one of the air flows while moistening the other.

Even though this known device allows for exchange of moisture between the two air flows, it exhibits some problems concerning the exchange efficiency since the moisture exchange rate is limited. This limitation in moisture exchange rate is to a large extent caused by unfavourable flow characteristics of the two air flows.

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Brief description of the invention

The present invention is based on the understanding that the exchange rate and thereby the efficiency of the device depends on the flow characteristics of the flows between which the exchange of substance is to be effected. One object of the

5. present invention is to provide a device for exchange of at least one substance between at least two counter-current fluid flows, which enhances the rate of substance exchange by creating more favourable flow characteristics of at least one of the fluid flows.

Another object of the invention is to provide such a device with which the exchange 10 rate is even more enhanced by creating favourable flow characteristics of both or all flows.

Still another object of the invention is to provide such a device with which the first flow inside the chamber, outside of the ducts is formed generally parallel and homogeneous over the cross section of the chamber.

- 15 Still another object of the invention is to provide such a device, with which turbulence is induced to one or both of the flows, in proximity to the duct walls.

These objects are achieved by a device according to the first paragraph of this description, which device is characterized by means for providing a generally parallel and uniform first fluid flow inside the chamber and/or means for inducing turbulence 20 to either or both of the fluid flows, in proximity to the duct wall.

The generally uniform and parallel first fluid flow created in the chamber, outside of the ducts contributes to enhancing the exchange rate by distributing the first fluid flow evenly over the entire length of all ducts inside the chamber.

- 25 The turbulence induced to the fluid flows in proximity to the duct walls also contributes to enhancing the exchange rate by avoiding that a boundary layer of stationary fluid is formed at the in- and/or outside of the duct walls, adjacent to the duct walls. Such a boundary layer would otherwise counteract efficient substance exchange, since it would prevent transport of the substance to be exchanged through this boundary layer.

Other objects and advantages of the invention appear from the dependent claims 2 –
10.

Description of embodiments of the invention

Exemplifying embodiments of the invention will be described below, with reference to

5 the accompanying drawings, fig. 1– 5, wherein:

Fig. 1 is a schematic drawing in perspective with parts broken away of a first embodiment of the device according to the invention.

Fig. 2 is a schematic side elevation cut through a vertical longitudinal plane of a device according to a second embodiment.

10 Fig 3 is a schematic drawing in perspective of the interior of a device according to a third embodiment of the invention.

Fig. 4 is a drawing according to fig. 3 of a fourth embodiment of the invention

Fig 5 is a computer generated model drawing of a device according to the invention.

In the described embodiment the fluids between which the moisture exchange is
15 effected are air, but it is contemplated that the device according to the invention also may be used for moisture exchange between other fluids, such as other gases. The device may also be used for exchanging other substances than moisture contained in the fluids, which fluids could comprise gases or liquids.

The embodiments of fig. 1 and 2 differ only in that a first inlet opening 5 and a first outlet opening 6 for an air flow A are arranged in different walls of the device. In the following reference is made to fig 1 and 2 irrespective of this difference.

The moisture-exchanging device shown in figs. 1 and 2 includes a centrally positioned chamber 1, as well as a first 4a and a second 4b adjacent side chamber, positioned at respective ends of the central chamber 1. The central chamber 1 is defined by four side walls 1a, 1b, 1c, 1d and two end walls 3a, 3b which later also constitute corresponding end walls of respective side chamber 4a, 4b. A plurality of fluid ducts 2 extend inside the central chamber 1, in parallel with the sidewalls 1a-1d and through the end walls 3a, 3b. The fluid ducts 2 are made of a membrane material

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having a high permeability to moisture but a low permeability to air. One portion of the sidewalls 1a-1d adjacent to the respective end walls 3a, 3b are made of a flexible material for allowing the side chambers 4a, 4b to move a certain distance to and away from the central chamber 1.

- 5 First open ends 2a of the fluid ducts 2 are arranged in the first side chamber 4a, which constitutes an inlet plenum for an air flow A. Second open ends 2b of the fluid ducts 2 are arranged in the second side chamber 4b, which constitutes an outlet plenum for the air flow A. A first inlet opening 5 for airflow A is arranged in one of the side walls of the first side chamber 4a and a first outlet opening 6 is arranged in one 10 of the side walls of the second side chamber 4b. A closed flow path for the first air flow A is thus provided from the first inlet opening 5 through the first side chamber 4a, the fluid ducts 2 and the second side chamber 4b to the first outlet opening 6.

The central chamber 1 exhibits a second inlet opening 7 and a second outlet opening 8 for another airflow B. The second inlet opening 7 is arranged in a sidewall 1a of the central chamber 1, in proximity to end wall 3b. The second outlet opening 8 is 15 arranged in proximity to end wall 3a and in another central chamber sidewall 1b, which is opposite to sidewall 1a. A closed flow path for the air flow B, which is counter-current to air flow A, is thus provided from the second inlet opening 7, through the central chamber 1 to the second outlet opening 8.

- 20 If e.g. moist exhaust air B is supplied to the central chamber 1 through the second inlet opening 7 and dry intake air is supplied to the ducts 2 through the first inlet opening 5 and the first side chamber 4a, the two air flows A and B will flow in a counter-current fashion through the central chamber 1 without being in direct contact with each other. During this counter-current flow, moisture from flow B will be 25 transmitted from flow B to flow A through diffusion through the membrane walls of the ducts 2.

According to the embodiment shown in fig. 4, a thin wire spiral 2c is arranged at the inner wall of each duct 2 in order to optimise the ability of flow A to absorb moisture. The wire spirals contribute to induce a turbulent flow inside the ducts 2. This turbulent flow prevents the formation of a boundary layer of stationary air adjacent to the inner walls of the ducts 2. Such a stationary boundary layer would otherwise deteriorate

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the absorption of moisture into flow A. Each wire spiral is formed as a preferably plastic, helical compression spring. The wire spirals thereby also contribute to keep the flexible membrane ducts 2 longitudinally stretched, so that sagging of the ducts is prevented. In order to achieve this, it is possible to select a suitable tensional force of 5 the wire springs, such as e.g. approximately 1/3 of the tensional strength of the ducts. Keeping the ducts stretched also contributes to achieve a uniform and parallel airflow B inside the central chamber 1, outside and around the ducts 2.

Alternatively, moist air A is supplied to the ducts 2 and dry air B is supplied to the central chamber. Also in such a case the wire spirals contribute to enhance the 10 moisture exchange from flow A to flow B. The wire spirals induce a turbulent flow inside the ducts B, whereby the formation of a desiccated boundary layer adjacent to the inner wall surfaces of the ducts 2 is prevented.

Instead of being arranged inside of the ducts 2, the wire spiral could also be arranged at the outside of the ducts. By this means, turbulence is induced to the air flow B, in 15 proximity to the outer surface of the duct walls. Hereby, formation of a stationary boundary layer of air flow B adjacent to the ducts is prevented. If desired, the wire spiral could also be omitted. In such a case turbulence could be induced to the flow inside and/or outside of the ducts, adjacent to the duct walls, by forming the duct wall material so that the inside and/or outside surface respectively of the ducts exhibits 20 turbulence inducing irregularities. E.g. the duct wall material could be constituted by coarse paper.

Fig. 3 illustrates means for creating a uniform and parallel air flow B inside the chamber according to one embodiment of the invention. Since the inlet opening 7 and outlet opening 8 of the central chamber are arranged in opposite side walls 1a, 25 1b, (fig 1 and 2) a problem to achieve a uniform and parallel air flow B inside the central chamber over its entire cross sectional area arises. Such a uniform and parallel airflow is of great importance for achieving effective and uniform moisture exchange over the entire active length of all ducts 2.

In order to solve this problem a number of support and flow distributing members 9a, 30 9b, 9c (see fig. 3) are arranged inside the central chamber 1, between the inlet opening 7 and the outlet opening 8. The members 9a-9c are arranged essentially

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- parallel to the cross section of the central chamber and cover essentially the entire cross sectional area. Each member 9a-9c includes a set of duct openings 10 through which the ducts extend. The duct openings 10 support the ducts 2 and are distributed over the area of respective member 9a-9c in a manner illustrated in figure 3, so that
- 5 the ducts 2 are uniformly distributed over the cross sectional area of the central chamber 1. This distribution of the duct openings 10 is preferred but if so desired, the duct openings and ducts may also be arranged in straight rows and columns, such as indicated in figure 1.

Each support and flow distributing member 9a-9c also presents a set of flow distributing openings 11a, 11b, 11c, which extend through the entire depth of the members 9a-9c, in the longitudinal direction of the ducts 2. All of the flow distributing openings 11b in the set of openings arranged in the centrally positioned member 9b have the same diameter. Whereas the diameter of the flow distributing openings 11a in the set of openings arranged in the member 9a, positioned closer to the inlet opening 7, vary over the cross section of the central chamber 1. The variation of diameter is configured in such a way that the flow distributing openings 11a' positioned adjacent to the sidewall 1a (fig 1and 2) containing the inlet opening 7 for air flow B have a smallest diameter. The diameters of the flow distributing openings increase gradually over the cross section of the central chamber 1, towards the side wall 1b being opposite to side wall 1a, so that the flow distributing openings 11a'', being adjacent to the side wall 1b, have a largest diameter. The support and flow distributing member 9c, being closer to the outlet opening 8, has a configuration of the variation of the flow distributing opening diameters which is corresponding but reversed to that of member 9a. I.e., in member 9c, the flow distributing openings 11c', positioned adjacent to the sidewall 1b containing the outlet opening 8, have a smallest diameter, whereas the flow distributing openings 11c'' at the opposite side wall 1a have a largest diameter.

The different diameters of the flow distributing openings 11a-11c create different pressure drop as the airflow B passes through the support and flow-distributing members 9a-9c. Air, which is supplied through the inlet opening 7, is hereby forced to be uniformly distributed in the inlet space, which is formed up-streams of the support and flow distributing member 9a, between this member 9a and the end wall 3b. At

the opposite end, which is adjacent to the outlet opening 8 of the central chamber 1 the same applies in a reversed manner. By this means, it is prevented that incoming air flow diagonally through the central chamber 1, from the inlet opening 7 to the outlet opening 8, such as would be the case without the arrangement of the especially designed and configured support and flow distributing members 9a-9c.

5 Hereby, a uniform and parallel airflow B is created over the entire length and cross section of the central chamber 1. This in turn contributes in great extent to an enhanced and more effective moisture exchange between the two airflows A and B.

In an alternative embodiment shown in figure 4, all of the flow distributing openings 10 11a'', 11b'' of the two endmost support and flow distributing members 9a, 9c are arranged with essentially the same diameter. For creating a varied pressure resistance over the cross sectional area of the respective support and flow distributing member, the number of openings per area varies over the cross section over the member. At the upstream member 9a, the number of openings 11a'' per 15 area increases with the distance from the sidewall 1a containing the inlet opening 7. At the downstream member 9c, the number of openings 11c'' per area decreases with the distance from the same sidewall 1a.

According to a not shown embodiment the flow distributing openings in one or several of the support and flow distributing members are arranged with essentially 20 the same diameter and with essentially the same number of openings per area over the entire support and flow distributing member. In such case, the uniformity and parallelism of the flow B, inside the central chamber may be enhanced by arranging the total volume of that portion of the central chamber which is positioned upstream of at least the most upstream support and flow distributing member great in relation 25 to the area of each opening. I.e. the volume of the central chamber between the upstream support and flow distributing member and the adjacent end wall should be large in relation to the area of each flow distributing opening in that support and flow distributing member.

In the embodiment shown in fig. 4, the centrally arranged support and flow 30 distributing member 9b is further formed as a grid, providing support to the ducts while presenting as little influence on the air flow as possible. The grid may be

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designed with different grid patterns between the support openings, in order to reduce the flow resistance while at the same time prevent the formation of any laminar flow components. The grid may e.g. be arranged with cross or diamond shaped supports between the duct support openings.

- 5 According to still another embodiment (not shown) and in order to further enhance the parallelism of the air flow B over the length of the central chamber, the support and flow distributing member positioned up-and down-stream in the central chamber adjacent to the inlet and outlet opening respectively, may be formed with a certain depth in the longitudinal direction of the ducts. By this means, the flow distributing
- 10 openings are formed as cylinders with a certain length, which corresponds to the depth of the support and distributing member. Such a cylindrical configuration of the flow distributing openings reduces any flow velocities in directions not parallel to the axial direction of the cylindrical openings, i.e. not parallel to the longitudinal direction of the ducts. Hereby, a flow B with an increased parallelism is created down-stream
- 15 the support and flow distributing member, which further enhances the effectiveness of moist exchange between the two air flows A and B.

The description of the embodiments above is given as an example only. It is evident that various changes and modifications may be made without deviating from the spirit and scope of the invention as claimed in the appending claims.

- 20 The central chamber and the side chambers may e.g. be cylindrically formed, whereby one continuous cylindrical wall constitutes the side wall of the chambers.

The Inlet and outlet openings for flow A may also, especially if the chambers are cylindrical, be arranged in the end walls of the side chambers.

Claims

1. Device for exchange of at least one substance, such as moisture, between at least two counter-current fluid flows (A, B), comprising a generally closed chamber (1) having an inlet (7) and an outlet (8) for a first fluid flow (B), such that the first fluid flow flows in a first direction from the inlet to the outlet inside the chamber; and at least one duct (2), which extends inside the chamber, generally in parallel with the first direction, which duct (2) is arranged to conduct a second fluid flow (A) in an opposite direction to the first direction and which duct (2) comprise a duct wall material with high permeability to the substance to be exchanged and low permeability to the fluids containing that substance, characterized by means for providing a generally parallel and uniform first fluid flow (B) inside the chamber and/or means for creating turbulence in either or both of the air flows (A, B) in proximity to the duct wall.
2. Device according to claim 1, comprising at least one support and flow distributing member (9a, 9c), being arranged inside the chamber (1) between the inlet opening (7) and the outlet opening (8), and having an extension in a plane which is non-parallel to the first direction, such that it extends over the essentially entire area of said plane inside the chamber, which support and flow distributing member comprises at least one duct opening (10) through which the at least one duct (2) extends and a set (11a, 11c) of flow distributing openings, which set of flow distributing openings is arranged for providing a parallel and uniform fluid flow (B) inside the chamber (1).
3. Device according to claim 2, wherein said set (11a, 11c) of flow distributing openings is arranged such that the sizes of the openings (11a', 11a'', 11c', 11c'') vary over the area of the support and flow distributing member (9a, 9c).
4. Device according to claim 2 or 3, wherein said set of flow distributing openings is arranged such that the number of openings (11a''', 11c''') per area varies over the area of the support and flow distributing member (9a, 9c).
5. Device according to any of claim 1 to 4, wherein the chamber (1) is defined by a number of side walls (1a, 1b, 1c, 1d) and two end walls (3a, 3b), said inlet (7) being arranged in a first (1a) of said side walls and said outlet (8) being arranged in a

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second side wall (1b), which is opposite to the first side wall, and wherein a first (9a) support and flow distributing member (9a) is arranged closer to the inlet (7) than a second (9c) support and flow distributing member, and which first support and flow distributing member comprises a first set (11a) of flow openings which is configured

5 so that the accumulated size of the openings (11a', 11a'', 11a''') per area of the support and flow distributing member increases with the distance from the first side wall (1a).

6. Device according to claim 5, wherein the second (9c) support and flow distributing member comprises a second set (11c) of openings, which is configured
10 so that the accumulated size of the openings (11c', 11c'', 11c''') per area of the support and flow distributing member increases with the distance from the second side wall (1d).

7. Device according to claim 5 or 6, wherein a third support and flow distributing member (9b) is arranged between the first (9a) and second (9c) support and flow distributing members, which third support and flow distributing member is configured
15 for providing a minimum flow resistance against the first air flow (B), while still inducing turbulence to disturb the formation of laminar flow between the ducts (2).

8. Device according to any of claim 1 to 7, wherein a wire spiral (2c) is arranged at
the inside of the duct wall for inducing turbulence to the second fluid flow (A), inside
20 the duct (2).

9. Device according to any of claims 1 – 8, wherein a wire spiral is arranged at the outside of the duct wall for inducing turbulence to the first fluid flow (B) in the chamber (1) in the proximity of the duct wall.

10. Device according to any of claim 1 – 9, wherein the duct wall material presents irregularities in the duct wall surface for inducing turbulence to the fluid flow (A, B) in proximity to the duct wall, on the inside and/or outside of the duct wall.
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Abstract

Device for exchange of at least one substance, such as moisture, between at least two counter-current fluid flows (A, B), comprising a generally closed chamber (1) having an inlet (7) and an outlet (8) for a first fluid flow (B), such that the first fluid flow flows in a first direction from the inlet to the outlet inside the chamber; and at least one duct (2), which extends inside the chamber, generally in parallel with the first direction, which duct (2) is arranged to conduct a second fluid flow (A) in an opposite direction to the first direction and which duct (2) comprise a duct wall material with high permeability to the substance to be exchanged and low permeability to the fluids containing that substance. In order to enhance the efficiency in substance exchange between the fluid flows, the device comprises means for providing a generally parallel and uniform first fluid flow (B) inside the chamber and/or means for creating turbulence in either or both of the air flows (A, B) in proximity to the duct wall.

Fig. 24
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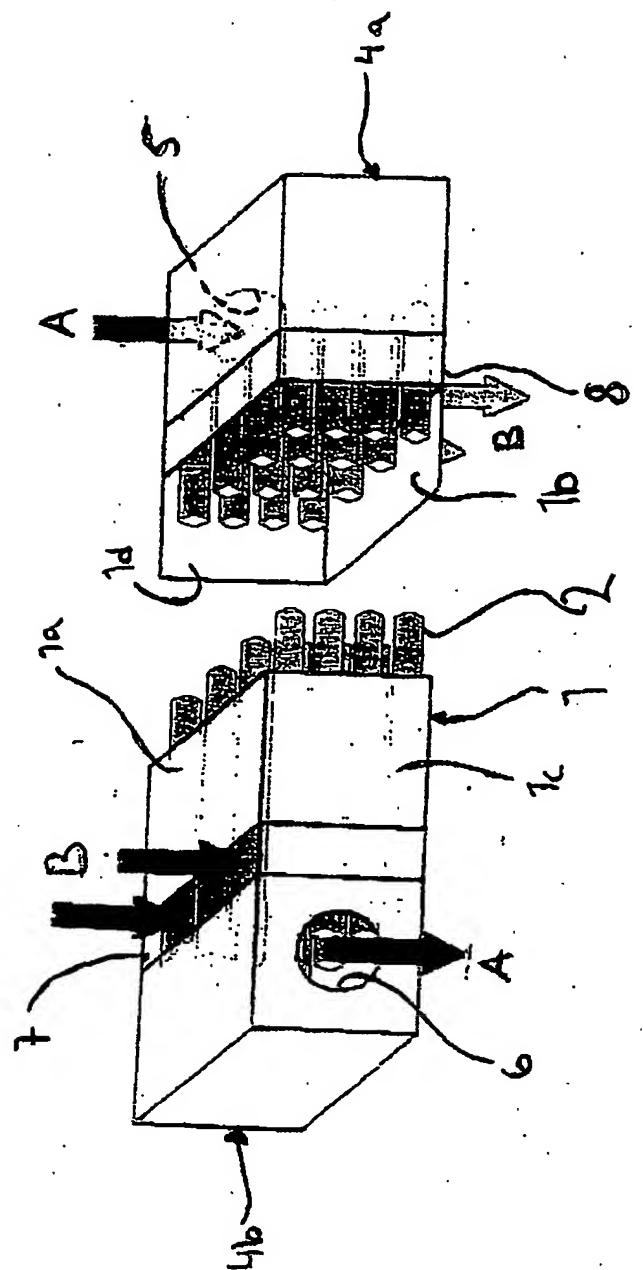
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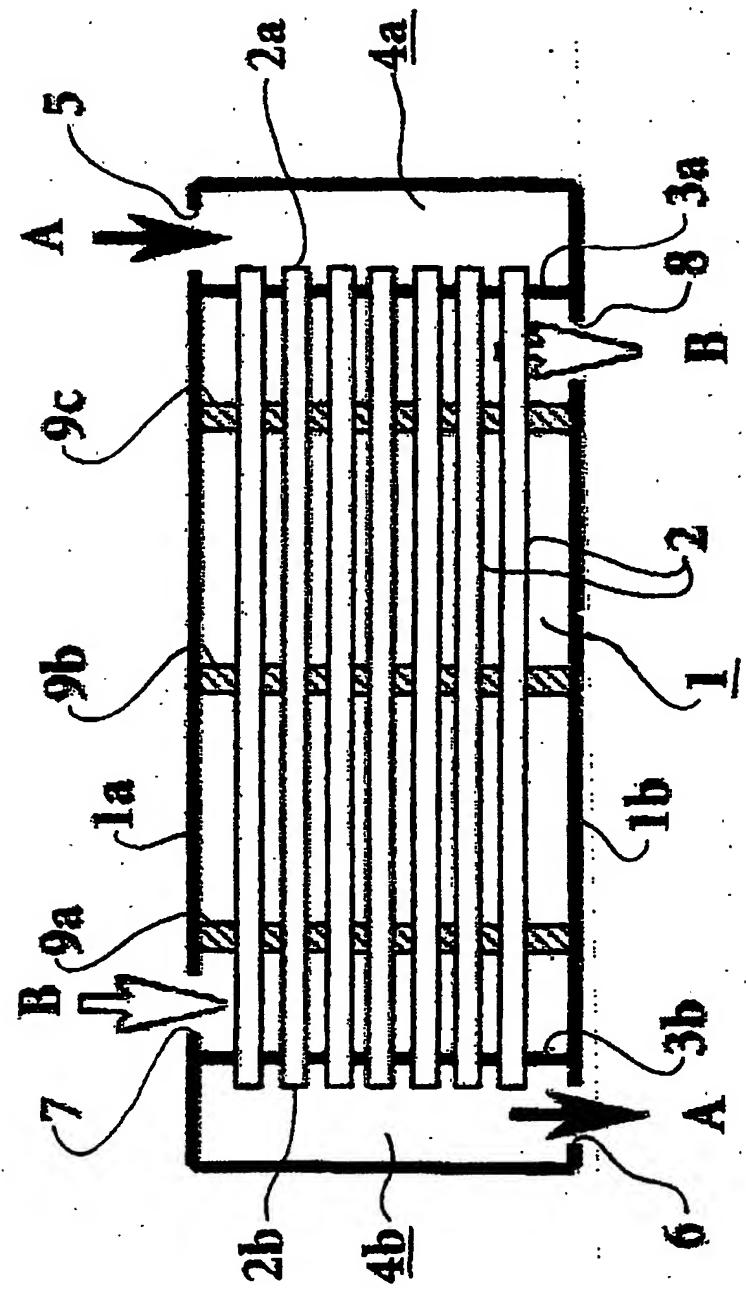


Fig. 2

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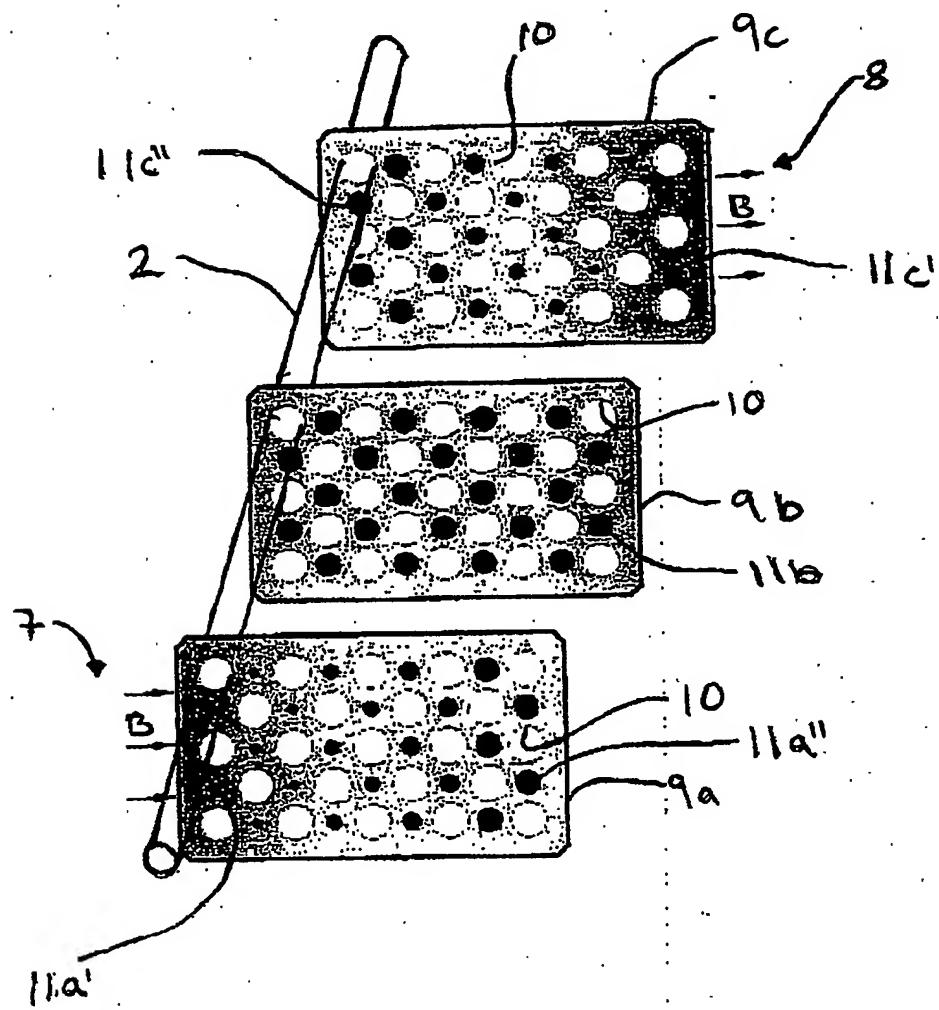


Fig 3

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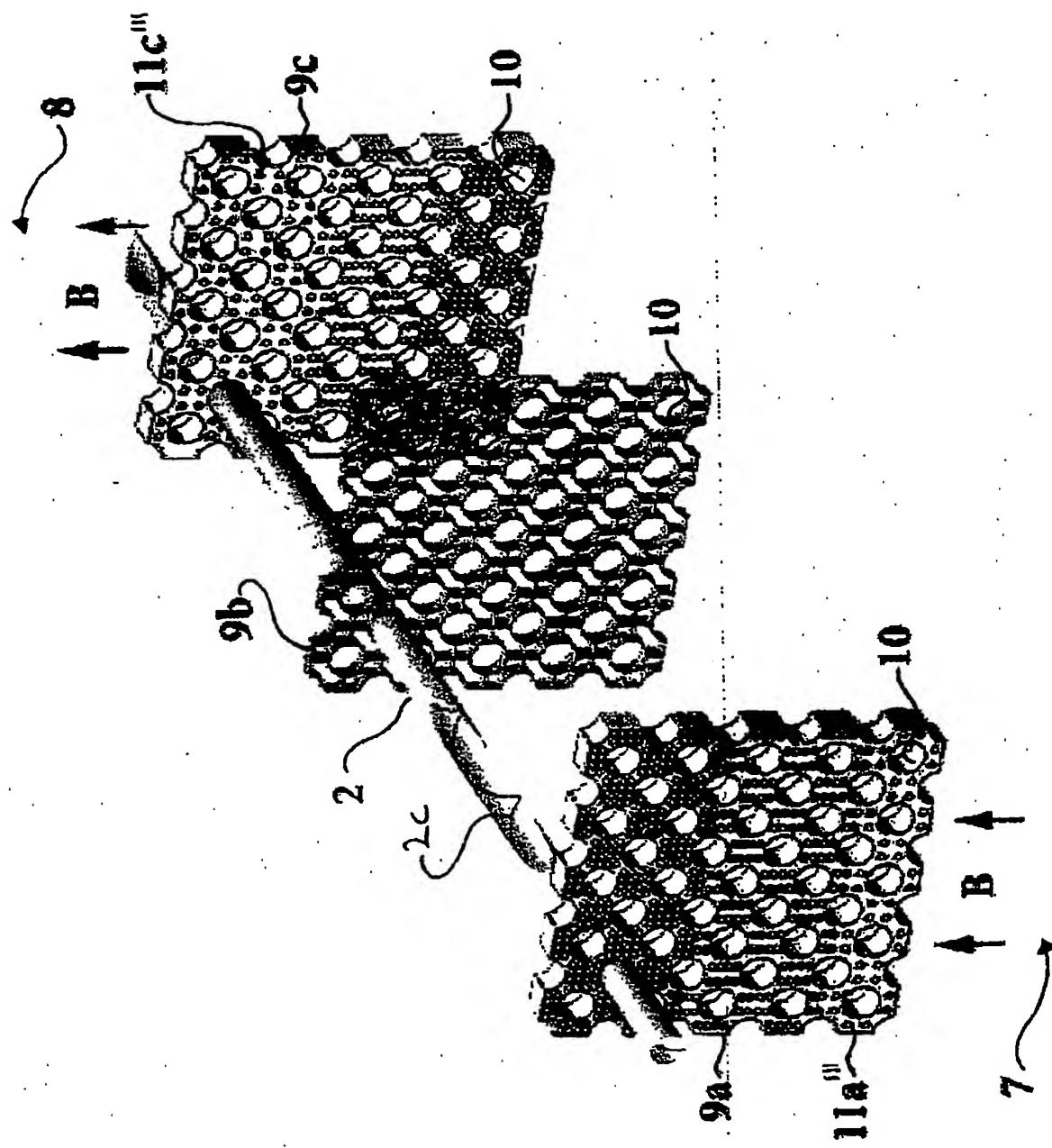


Fig 4

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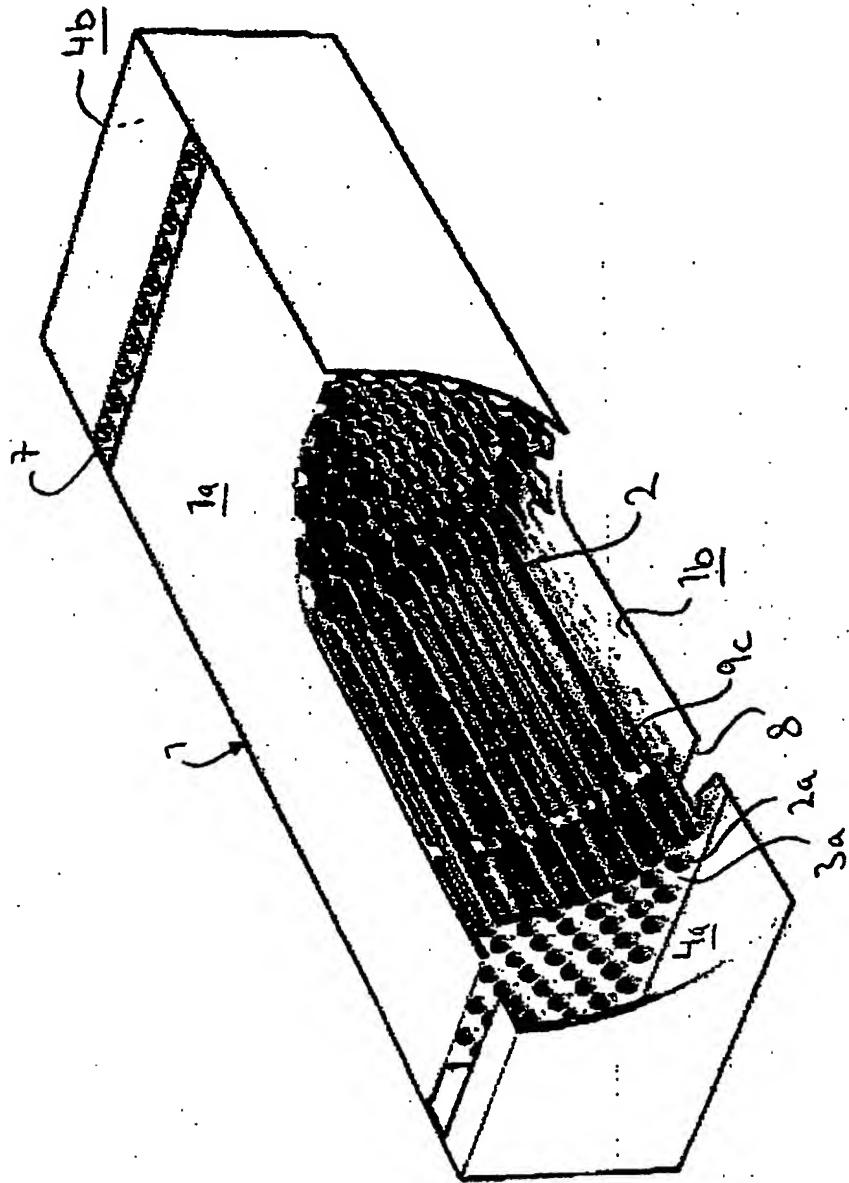


Fig. 5